LARGE AREA NONPOLAR OR SEMIPOLAR GALLIUM AND NITROGEN CONTAINING SUBSTRATE AND RESULTING DEVICES

RELATED APPLICATIONS

This application claim priority to U.S. provisional application, 61/507,829, filed on Jul. 14, 2011, entitled "LARGE AREA NONPOLAR OR SEMIPOLAR GALLIUM AND NITROGEN CONTAINING SUBSTRATE AND RESULTING DEVICES", which is hereby incorporated by reference in its entirety.

BACKGROUND

This disclosure relates generally to lighting, and embodiments of the disclosure include techniques for fabricating a large area non-polar or semi-polar gallium and nitrogen containing substrates using nucleation, growth, and coalescing processes. The disclosure can provide substrates for LEDs for white lighting, multi-colored lighting, flat panel displays and other optoelectronic devices.

In the late 1800's, Thomas Edison invented the light bulb. The conventional light bulb, commonly called the "Edison bulb," has been used for over one hundred years. The conventional light bulb uses a tungsten filament enclosed in a glass bulb sealed in a base, which is screwed into a socket. The socket is coupled to AC power or DC power. The conventional light bulb can be found commonly houses, buildings, and outdoor lightings, and other areas requiring light. Unfortunately, the conventional light bulb dissipates about 90% of the energy used as thermal energy. Additionally, the conventional light bulb routinely fails often due to thermal expansion and contraction of the filament.

Solid state lighting techniques are known. Solid state lighting relies upon semiconductor materials to produce light emitting diodes (LEDs). Red LEDs use Aluminum Indium Gallium Phosphide or AlInGaP semiconductor material. Most recently, Shuji Nakamura pioneered the use of InGaN materials to produce optoelectronic devices emitting light in the violet, blue, and green color range for LEDs and laser diodes. The blue and violet colored LEDs and laser diodes have led to innovations such as solid state white lighting.

GaN-based devices fabricated on bulk GaN substrates with nonpolar or semipolar crystallographic orientations have been shown to have certain favorable characteristics, such as improved efficiency at high current densities and/or elevated temperatures. Most such substrates, however, have been limited in size, with lateral dimensions of about 5 mm wide by 15 mm long. This size limitation, together with relatively high cost, has significantly limited the development and implementation of nonpolar and semipolar GaN-based devices. What is needed is a cost effective means for fabricating large area nonpolar and semipolar bulk GaN substrates, together with methods for fabricating high performance, low cost LEDs and laser diodes on these substrates.

BRIEF SUMMARY

In a specific embodiment, the method includes providing a gallium and arsenic containing substrate having a major surface region and forming a plurality of recessed regions within a thickness of the substrate. Preferably, each of the recessed regions has a first exposed surface of a first crystallographic orientation and a second exposed surface of a second crystallographic orientation. Masking material is formed over at least the first exposed surface of each of the recessed regions, and a nucleation material is formed over the second exposed surface of each of the recessed regions. Gallium and nitrogen containing material are then formed over the nucleation material to fill the recessed regions to form growth structures in each of the recessed regions. The growth structures are then coalesced to form a thickness of a gallium and nitrogen containing material. Then a step of releasing the resulting thickness of the gallium and nitrogen containing material is performed to separate it from at least the major surface region.

The present method provides for fabrication of cost-effective, large area nonpolar and semipolar bulk GaN substrates. The substrates may be used as seed crystals for subsequent bulk crystal growth. In addition, the method enables fabrication of cost-effective, high-performance LEDs and laser diodes. The present method and resulting device can be fabricated using known process equipment, which is easy and cost effective to scale.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1** through **4** are diagrams illustrating a method of fabricating a large area substrate;

FIGS. **5** through **10** are diagrams illustrating an alternative method of fabricating a large area substrate; and

FIGS. **11** through **14** are diagrams illustrating a method and resulting optical devices according to embodiments of the present disclosure.

FIGS. **15** and **16** depict steps for practicing method embodiments.

DETAILED DESCRIPTION

Referring to FIGS. **1** through **4**, a method of fabricating a large area nonpolar substrate according to an embodiment of the present disclosure is outlined below.

1. Referring first to FIG. **1**, supply a large-area substrate **110**, for example of GaAs. The substrate orientation may be chosen so that the [111]A direction lies in the plane of the surface. For example, the large-area surface may have a (110) orientation.
2. Deposit a masking layer **120**, e.g., a photoresist, SiO_x, or SiN_x, SrF_2, or Ni onto the surface, with a thickness of approximately 50 nm-1 micron. Pattern the surface into strips by conventional photolithography with an array (e.g., a one-dimensional or linear array, a two-dimensional array, etc.) of masks or mask strips, with the edges of the masks lying along the intersection of (111)A surfaces with the large-area surface. The openings between the masks **130** may have a width w between about 1 micron and about 10 microns and the pattern has a period L between about 2 microns and about 5000 microns, preferably between about 5 microns and about 1000 microns.
3. Form etched trenches **150**, with a depth d between about 1 micron to about 10 microns, with sidewalls that are vertical to within 30 degrees, for example, by reactive-ion etching with $Cl_2/BCl_3/SiCl_4$ and/or with $CF_4/CHF_3/SF_6/O_2/Ar/N_2$. Optionally, wet-etch to remove damage and prepare a plurality of smooth surfaces **140** with an orientation within degrees of (111)A.
4. Referring next to FIG. **2**, deposit a layer of masking material **220**, e.g., comprising SiO_x or SiN_x, onto the surface, with a thickness of 50 nm-1 micron, by directional deposition **210**, e.g., sputtering, ion beam deposition, onto the non-(111)A surfaces.
5. Deposit a low-temperature nucleation layer and a high-temperature GaN epitaxial layer **230** on the (111)A sur-